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ORIGINAL ARTICLE • UPPER LIMB - FRACTURES

Submuscular double bridge plating for complex distal fractures of the humerus: an alternative, safe, and efficient treatment method

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Abstract
Purpose The aim of our study is to show the functional outcomes and complication rates of humeral complex fractures in adults, using osteosynthesis with two bridging orthogonal submuscular plates.
Methods The study consists of a prospective case series of 13 patients with isolated humeral complex fractures treated with two bridging orthogonal submuscular plates. Functional assessment was performed using disabilities of the arm, shoulder, and hand (DASH) score with 30 items. The age ranged from 22 to 68 years, with a mean age of 39 years. Functional assessment with DASH score was performed at the twelfth postoperative week.
Results All patients presented fracture healing in the fourth postoperative month. Of the 13 patients, five (38%) had a DASH score of zero (best function possible). One patient developed neuropraxis and presented with a score of 100 (worst possible). One case developed superficial infection, which was treated with oral antibiotics and local debridement.
Conclusions This study demonstrated satisfactory functional outcome in patients with distal-third diaphyseal humeral complex fractures treated with two locked submuscular plates. The authors consider it as a safe method and an efficient alternative, especially in younger patients who require early functional recovery.

Keywords Humeral fractures · Treatment outcome · Fracture fixation

Introduction

Humeral shaft fractures are very common and account for approximately 4% of all fractures. Historically, they have a nonsurgical approach due to the plentiful vascularization of the humerus and low incidence of nonunion [1]. Distal-third diaphyseal humeral complex fractures represent an additional challenge to the orthopedic surgeon due to the difficulty of controlling angular deformities [2]. Criteria determined as "good results" were created empirically [3]. General practice employs the rule of "20 degrees of angulation" to indicate surgical treatment. Such statement is not supported in scientific the literature, however, remains as fact in many subsequent studies [4, 5].

There is no consensus on the best alternative in the treatment of distal humeral complex extra-articular fractures. Standard surgical treatment with compression plating is performed with a posterior [6] or lateral access [7]. Minimally invasive percutaneous plate osteosynthesis can also be performed using anterior [8] or posterior approach [9].

The aim of this study is to show the functional outcomes and complication rates of surgical treatment for complex distal humeral fractures in adults, using osteosynthesis with two bridging orthogonal submuscular plates in a posterior approach.

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We hypothesized that submuscular precontoured distal humeral locking plates preserve bone biology and provide adequate stability for early rehabilitation, thereby diminishing complication rates.

Materials and methods

Subject cohort

The study consists of a prospective case series. Cases were consecutive included. The inclusion criteria were adults with distal-third diaphyseal humeral complex fracture established by a plain film in anteroposterior and lateral radiographs. Exclusion criteria were patients with age less than 18 years old, associated fractures, previous humeral fractures, anatomical abnormality in the upper limb, and presence of relevant clinical comorbidities. This study was approved by our local ethical committee on the number 44198815.0.0000.0073.

Fractures were classified accordingly to AO/OTA [10] as types B and C. All patients were operated on by the same surgical staff using precontoured locking compression plates 3.5 mm DePuy SynthesTM.

Functional assessment was performed using DASH score (disabilities of the arm, shoulder, and hand) with 30 items, translated to the local language. Clinical score was obtained 12 weeks postsurgery [11].

Fracture union was defined as bridged cortices on two radiographic planes and absence of pain during movement.

Thirteen patients were treated between January 2014 and February 2015. Nine were males and four were females. The age ranged from 22 to 68 years, with a mean age of 39 years. Patients were followed for 12–20 months with an average of 16 months. Nine (69.2%) patients were victims of automobile accidents.

Surgical technique

All surgeries were performed under general anesthesia. Patients were positioned prone with the affected limb on a radiolucent table, allowing at least 90 degrees of elbow flexion. Then, during anesthesia induction, antisepsis with chlorhexidine and antibiotic prophylaxis were completed. Tourniquet was not used to avoid limiting movement of the triceps. For fracture fixation, we used three surgical posterior windows: the proximal, to identify the radial nerve; the medial–distal, to perform exploration and protection of the ulnar nerve and fracture fixation with the medial plate; and the distal–lateral, to introduce the posterolateral plate.

An extensive skin incision was used, which was in the midline of the posterior arm, in the plane between the lateral and medial cutaneous nerves with lateral deviation in its distal portion, at the elbow level. The lateral deviation was chosen to prevent scaring close to the ulnar nerve and minimize the pain related to the patient support of the elbow on rigid surfaces close to the scar.

The triceps fascia was split into two halves and elevated with the dermis and the subcutaneous tissue, creating a large flap that contributes to good healing (Fig. 1).

Dissection of the distal submuscular region was performed according to the technique described by Schildhauer et al. [12].

The lateral access was defined by elevating the triceps in a subperiosteal way toward the medial aspect of the arm. The radial nerve is about 10 cm proximal to the elbow, where it crosses from posterior to anterior (Fig. 2). Distally, dissection reached the anconeus muscle level.

The medial–distal approach was performed after the medial triceps dissection, isolating and removing the ulnar nerve from the cubital tunnel up to its first branch (Fig. 3).

These two windows communicate by elevating the triceps posteriorly, allowing for length and rotation control through indirect manipulation of the fragments.

Then, dissection of the proximal window was performed 2.5 cm above the apex of the triceps aponeurosis [13]. Following the proximal dissection technique described by

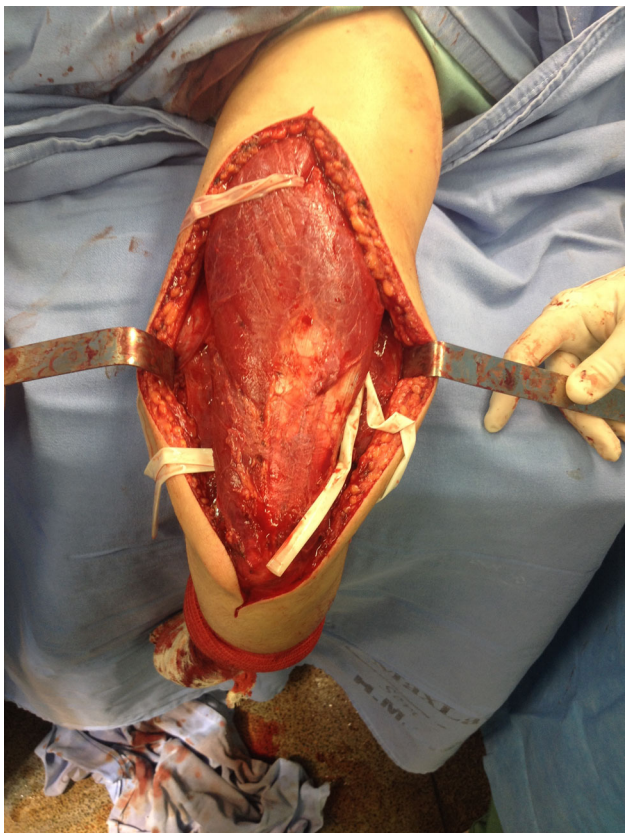

Fig. 1 Initial dissection showing a large subcutaneous flap

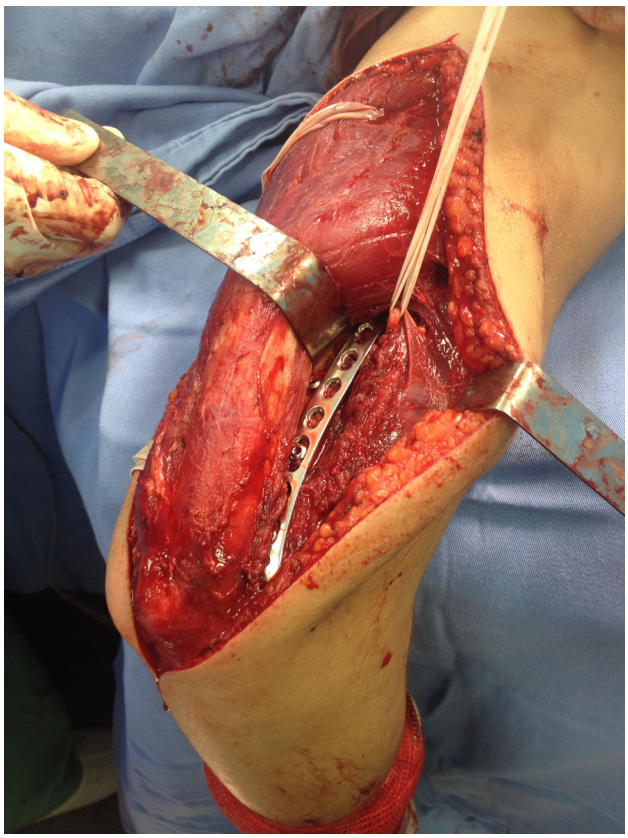

Fig. 2 Intraoperative photograph showing the surgical exposure of the posterolateral plate and radial nerve

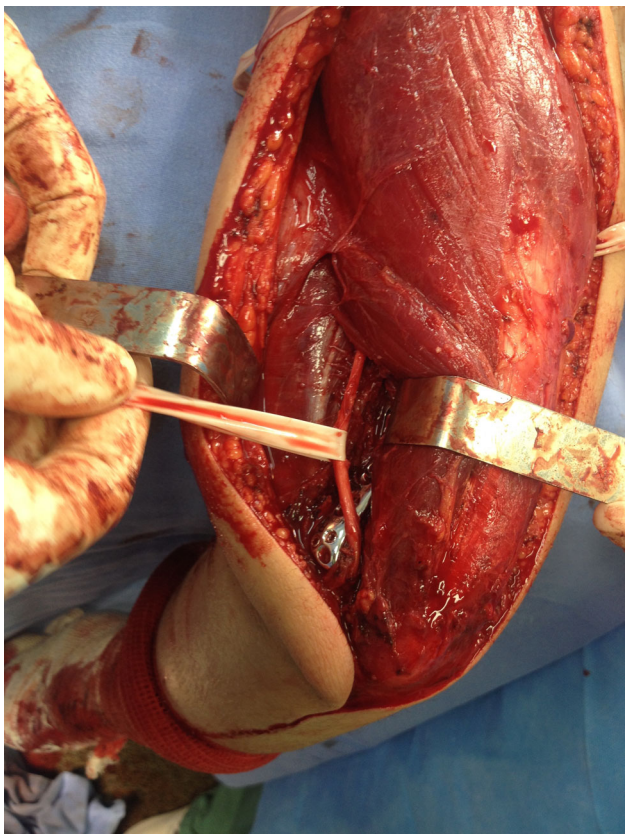

Fig. 3 Intraoperative photograph showing medial plate and ulnar nerve

Balam et al. [9], the proximal window was performed distally to the posterior margin of the deltoid and triceps head. At this level, an area shaped like a "V" between the lateral and the long triceps heads was identified. The radial nerve was identified and carefully pulled up in this region for the insertion of the plates. It is possible to feel the radial nerve in its pathway by placing the digital along the nerve direction (Fig. 4).

Plates were placed in a retrograde manner from distal to proximal. Initially, the posterior plate is placed in the lateral column. A Kirschner wire was used to temporarily fix the most distal hole of the plate to the bone. Subsequently, a 3.5-mm cortical screw fixed proximal oval hole in the plate. It is recommended not to tighten the screw.

Subsequently, the medial plate was slid from distal to proximal in the medial column of the humerus. The shoulder, then, was rotated internally, and the plate was fixed in the same manner as the posterior plate. Correct positioning was checked fluoroscopically, and additional screws were added to provide relative stability.

The fascia was closed with absorbable sutures of size 1.0, subcutaneous with 2.0, intradermic sutures with 3.0, and the skin sutured with simple stitches of Nylon 4.0. Drains were not used.

Patients were discharged one day after surgery and did not use any orthotics or sling. Postoperative analgesia included opioids and standard analgesics for 7 days.

Postoperative rehabilitation protocol was divided into:

Passive movements, starting in the very early postoperative period until the third week after surgery, especially elbow extension.

Suture removal and active movement of shoulder and elbow, starting in the third week until maximum range of motion.

Results

The average surgery time was 110 min, ranging from 80 to 140 min. Blood loss was minimal and no patients required a postoperative transfusion.

Fracture union was evaluated in the fourth postoperative month, and all patients presented fracture healing (Fig. 5a, b).

DASH results are shown in Table 1. Of the 13 patients, five (38%) had a score of zero. One patient developed neuropraxis and presented with a score of 100 (worst possible). This patient presented with neurological

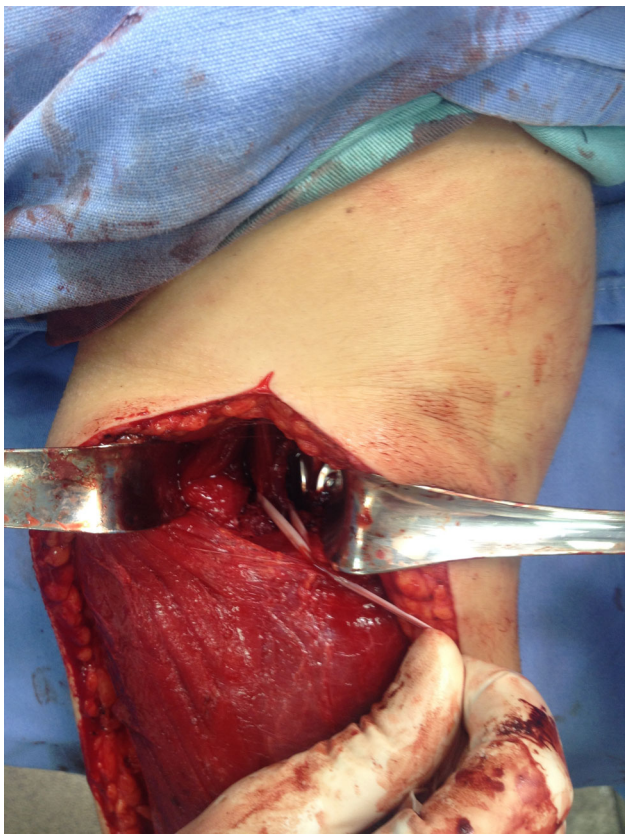

Fig. 4 Intraoperative photograph showing proximal window with both plates and radial nerve

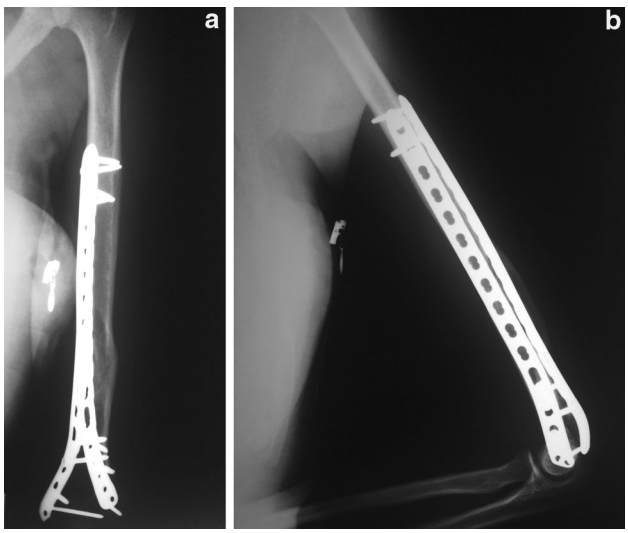

Fig. 5 Radiographs of the humerus following open reduction. Anteroposterior (**a**) and lateral (**b**) radiograph demonstrating plate position and bone callus

recovery 6 months after surgery, starting with active extension of the wrist and fingers. One case developed superficial infection, which was treated with oral antibiotics and local debridement.

Discussion

The current literature lacks a consensus for extra-articular distal humeral complex fractures [14].The current study showed promising functional outcomes and low complication rates with surgical treatment using posterior approach and fixation with two precontoured locking submuscular plates.

Despite the satisfactory results reported in the literature with conservative treatment, it is noteworthy that simple fracture patterns account for about two-thirds of the cases and most studies do not make a distinction between simple and complex fractures [15].

Treatment of complex fractures is known to be more demanding [2]. We believe fracture fixation must be rigid enough to promote early mobilization of the limb.

Livani et al. [8] described the bridging stabilization technique of humeral shaft fractures though an anterior approach. For more distal fractures, the authors recommend a narrow DCP plate of 4.5 mm in the radial column of the humerus. The stability achieved by fixation with DCP plates depends on the contact between plate and bone. Depending on the range of motion of the fracture, fixation may become unstable before complete bone union. Ziran et al. suggested the use of locked plates in the treatment of shaft fractures by relative stability to increase the rotational stability and load bearing capacity in the fracture consolidation period [16].

The use of two orthogonal plates increases rotational stability [17]. Thus, it is possible to allow patients full and unrestricted movement of the shoulder and elbow in the immediate postoperative period. We hypothesized that this modification would improve the functional outcome of our patients.

This study has some limitations. The study design (case series) does not allow comparison with other fixation methods. Additionally, functional evaluation was not performed at multiple time points to allow for more objective follow-up. Fixing plates positioned in two orthogonal planes at the same level of the fracture can create an area predisposed to peri-implant fractures. We did not have any cases of peri-implant fractures, but our follow-up did not allow for definitive conclusions about increased risk for these injuries. We also did not compare costs when analyzing this technique and other fixation methods.

On the other hand, this is a new technique for fixing complex humeral shaft fractures with good functional results. The primary hypothesis of the authors of good functional results with increased fracture stability by placing a second locked plate was confirmed. The indirect reduction of the fracture made on the "mold" of two anatomical plates minimizes the risk of angulations. We

Table 1 Patient data, injury mechanism, functional outcome, fracture classification and complications

Gender	Age	Mechanism	DASH	AO 12 classification	Complications
M	25	Motorcycle accident	11,6	B	
M	42	Vehicle collision	0	B	
F	34	Motorcycle accident	100	C	Radial neuropraxis
M	30	Arm wrestling	10	B	
M	45	Motorcycle accident	0	B	
M	40	Motorcycle accident	17,5	C	
F	39	Running over	12,5	B	
F	54	Motorcycle accident	24	C	Superficial wound infection
M	29	Sports trauma	0	B	
M	22	Running over	0	B	
M	68	Fall	20	B	
M	47	Fall	42	B	
F	32	Motorcycle accident	0	C	

observed that all patients in this series had their fractures healed within 12 weeks. This finding emphasizes the biological character of fixation, preserving surrounding soft tissue.

This technique allows for free movement of the limb from the immediate postoperative period with minimal muscle dissection. Thus, this technique provides a minor muscle injury and sufficient stability for immediate load. It can be used in patients requiring immediate restoration of movement, such as athletes, laborers, and multiple trauma patients that require rehabilitation of other injuries, and other professionals, as well.

Further research should focus on clinical trials comparing this technique with conservative treatment, open reduction and internal fixation with plates and screws, as well as single anterolateral bridge plating. Biomechanical studies comparing the double plate stiffness with the single anterolateral plate are also necessary to confirm the clinical hypothesis of the present study.

Conclusion

This study demonstrated satisfactory functional outcome in patients with distal-third diaphyseal humeral complex fractures treated with two locked submuscular plates. This treatment has shown to be promising. Complication rates are similar to others reported in the literature with conventional methods. The authors consider it as a safe method and an efficient alternative, especially in younger patients who require early functional recovery.

Compliance with ethical standards

Conflict of interest The author(s) declare that they have no competing interests.

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